Unit - 4.

DC Machines

DC Machine whether a generator or motor.

DC machine parts :- Field magnets, Armature, Commutator, Brushes, Armature winding, Bearing, Shaft.

EMF Equation :-

the induced EMF $e = \frac{d\phi}{dt}$

flux cut by one conductor in one revolution $= P\phi$ weber

flux cut by each conductor per second = flux cut by one conductor revolution x number of revolutions of armature per second $\Rightarrow \phi P \times \frac{N}{60}$ weber

average EMF induced in one conductor will be

$$e = P\phi \frac{N}{60} \text{ volts}$$

number of armature conductors per parallel path $= \frac{Z}{A}$

In wave winding $A = 2$

In lap winding $A = P$

Z = number of slots × number of coil sides per slot × number of turns in each coil

total EMF generated between the terminals

E = Average EMF induced in one conductor × number of conductors in each circuit or parallel path

$$E = P\phi \frac{N}{60} \times \frac{Z}{A} \text{ volts}$$

$$E = \phi Z \frac{N}{60} \times \frac{P}{A} \text{ volts}$$

P = number of poles
A = number of parallel path in armature
N = rotational speed of armature in rpm.
Z = number of armature conductors

In machine P and $\frac{Z}{A}$ are constant

$$E = K\phi N \qquad \because K = \frac{PZ}{60A}$$

$$E \propto \phi N$$

$$E \propto \phi \omega$$

$\because \omega = \frac{2\pi N}{60}$ the angular velocity in radian per second

The polarity of the induced EMF depends upon the direction of the magnetic field and the direction of rotation.
If direction are reversed the polarity of the induced EMF is reversed but both directions are reversed the polarity remains unchanged.

The Induced EMF is fundamental phenomenon to all dc machines whether they are oprating as generator or motors.

in generator generated EMF = E_g

in motors back EMF = E_b
(counter EMF)

Types of DC Generators :-

(1) Separately - Excited DC Generator :-

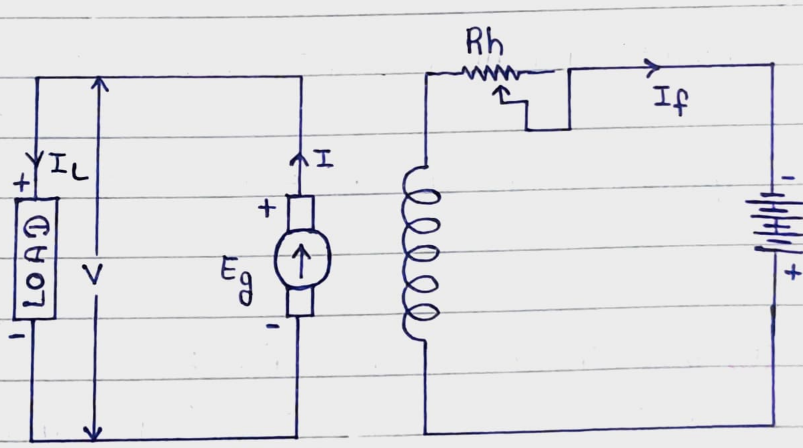
A dc generator whose field winding is excited from an independent external dc source the generator is called a separately-excited generator.

$I_a = I_L = I$

$V = E_g - I_a R_a$

power developed

$P_g = E_g I_a = E_g I$



power delivered to external load

$P_L = V I_L = V I$

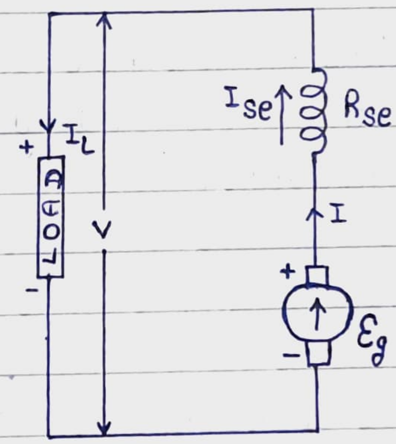
(2) Self - Excited DC Generator :-

A dc generator whose field winding is excited by the current supplied by the generator itself, is called a self - excited generator.

The field coils may be connected either in series and in parallel with the armature. ~~winding~~
or partly in series and partly in parallel with the armature.

(1) Series Wound generator :- In a series wound generator there is only one field winding. which is connected in series with armature winding so that whole current flows through the field winding as well as load.

$I_a = I_{se} = I_L = I$



$V = \mathcal{E}_g - I(R_a + R_{se})$

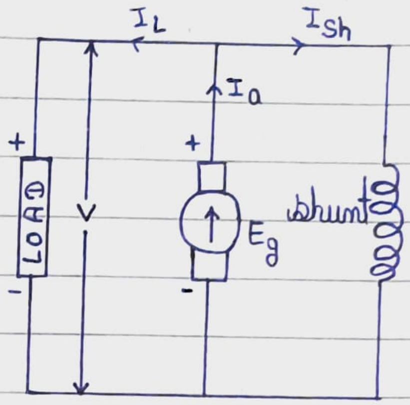
power developed, $P_g = \mathcal{E}_g I_a = \mathcal{E}_g I$

power delivered, $P_L = V I_L = VI$

(2) Shunt Wound generator :- In a shunt wound generator also there is only one field winding as in case of series wound generator, but in this case it is connected across the armature circuit forming a parallel or shunt circuit. The voltage across the field winding is therefore the same as the terminal voltage of the generator.

$I_a = I_L + I_{sh}$

$I_{sh} = \frac{V}{R_{sh}}$



terminal voltage, $V = E_g - I_a R_a$

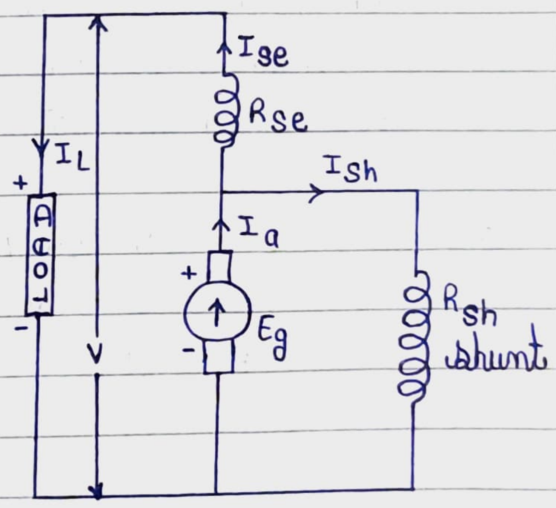
power developed, $P_g = E_g I_a$

power deliverd, $P_L = V I_L$

(3) Compound Wound generator :- In compound wound generator there are two field windings. One of them is connected across the armature and the other is connected in series with the armature winding.

(a) Short - Shunt Compound wound generator :-

$I_{se} = I_L$



shunt current, $I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}}$

armature current,

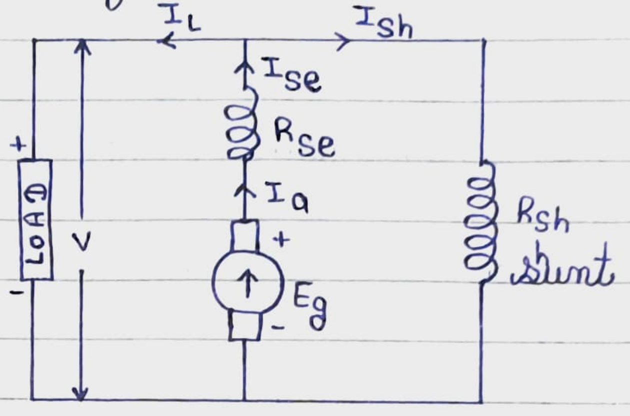
$I_a = I_{sh} + I_{se}$

$V = E_g - I_a R_a - I_{se} R_{se}$

$P_g = E_g I_a$

$P_L = V I_L$

(b) Long - shunt compound wound generator :-



shunt current, $I_{sh} = \frac{V}{R_{sh}}$

$I_a = I_{se} = I_L + I_{sh}$

$V = E_g - I_a R_a - I_{se} R_{se}$

$V = E_g - I_a R_a - I_a R_{se}$

$V = E_g - I_a (R_a + R_{se})$

power developed, $P_g = E_g I_a$

power delivered, $P_L = V I_L$

Ex:- 1. A 4- poles dc shunt generator with lap- connected armature supplies of a load 100A at 200V. The armature resistance is 0.1 Ω and the shunt field resistance is 80 Ω. find the total armature current and emf generated

sol^n:-

$V = 200V$

$I_L = 100A$

$R_a = 0.1\,\Omega, \; R_{sh} = 80\,\Omega$

$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{80} = \frac{20}{8}A = 2.5A$

$I_a = I_L + I_{sh} = 100 + 2.5 = 102.5A$

$E_g = V + I_a R_a = 200 + 102.5 \times 0.1 = 200 + 10.25 = 210.25\,V$

Working principle of DC Motor :-

If a current carrying conductor is placed in a magnetic field, mechanical force is experienced on the conductor, the direction of which is given by fleming's left hand rule and hence the conductor moves in the direction of force.

mechanical force $F = B I_c L_c$

When the motor is connected to the dc supply, a direct current passes through the brushes and commutator to armature winding; while it passes through the commutator it is converted into Ac so that the group of conductors under successive field poles carry current in the opposite directions.

The current in armature conductor be outwards under the N- poles and inwards under S- poles. Each conductor experiences a force which tends to rotate the motor armature in clockwise direction.

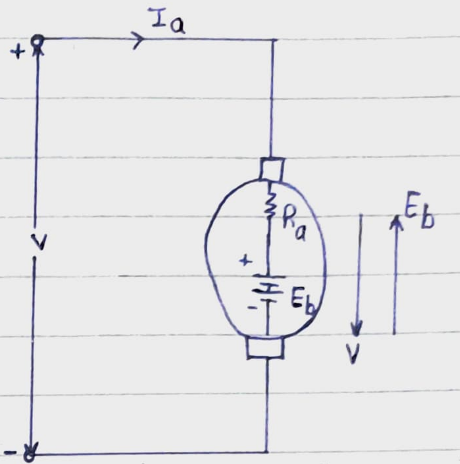
Importance of Back EMF :-

The motor armature rotate the due to motor action, the armature conductors cut the magnetic flux and induced an EMF. The direction of this induced EMF known as back EMF it is opposes the applied voltage.

$$\text{Back EMF} = E_b = P\phi \frac{N}{60} \times \frac{Z}{A}$$

$$V = E_b + I_a R_a$$

$$I_a = \frac{V - E_b}{R_a}$$



E_b depends among other factors upon the armature speed and armature current depends upon the back EMF - for a constant applied voltage and armature resistance.

If armature speed is high, E_b large and armature current low.
If armature speed is low, E_b will less and armature current high to developent of large torque.

The presence of back emf makes the dc motor a self regulating machine. When the motor is operating on no load small torque is ~~required load torque~~ is required to over come the friction and winding losses, back EMF is nearly equal to the applied voltage and armature current is small. When the motor is loaded, the driving torque of the motor is not sufficient to counter the increased retarding torque due to load and the effect is to cause the armature to slow down. Armature speed will decrease back emf falls. The reduced back emf allows a large current to flows through the armature. The increases in armature current results in higher electromagnetic driving torque. The motor continus to

slow down till the electromagnetic torque developed matches the load torque and the steady-state conditions are attained. The reverse phenomenon occurs when mechanical load on the motor falls.

When the load on the motor falls, the electromagnetic torque developed is momentarily in excess of the load requirement and therefore the motor armature accelerates. Armature speed will increase, back emf increases causing armature current to decreases. The decrease in armature current causes decrease in electrommagnetic torque and the steady-state conditions are attained when the electromagnetic torque developed matches the load torque.

Thus it is evident that back emf E_b are acts like a governor that is it makes a motor self-regulating so that it draws as much current as just required.

Types of DC Motors :-

(1) Permanent Magnet Motor :-

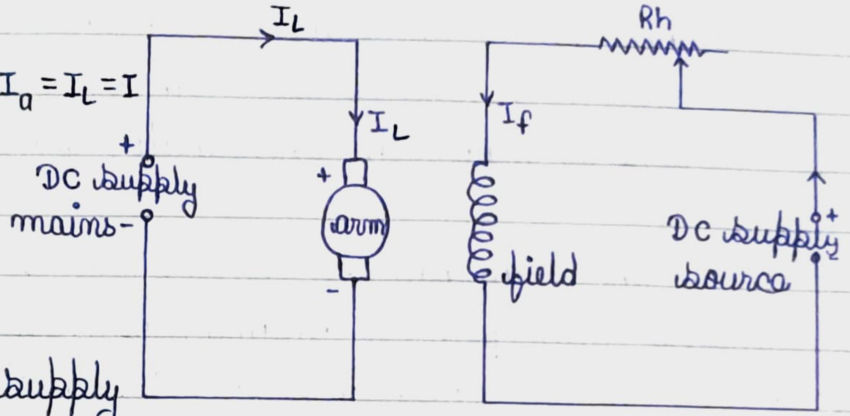
It consists of an armature and one or several permanent magnets encircting the armature. Field coils are usually not required. Some of these motors do have coils wound on the poles. If they exist, these coils are intended only for recharging the magnets in the event that they lose their strength. This motor appears as only an armature.

(2) Separately Excited DC Motors :-

Armature current $= I_a = I_L = I$

Back emf $= E_b = V - I_a R_a$

$E_b = V - I R_a$



Power drawn from supply mains, $P = VI$

Mechanical power developed

P_m = power input to armature - power lost in armatu

$$P_m = VI_a - I_a^2 R_a = VI - I^2 R_a$$

$$P_m = I(V - IR_a) = I E_b$$

(3) Series Wound DC Motors :-

The field coils, consisting of few turns of thick wire, are connected in series with the armature. The cross-sectional area of the wire used the higher current, the number of turns of wire in them need not be large.